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Filling distribution gaps of a little-known endemic species, *Rojasianthe superba* Standl. & Steyerm. (Asteraceae) in northern Central America

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Abstract

Rojasianthe superba Standl. & Steyerm. (Asteraceae) is an endemic species, limited to a few localities in Mexico and Guatemala. Here we report a new occurrence point at a departmental scale in Guatemala; it also extends its known distribution by 40 km to the northeast. We ran species distribution models (SDM) to evaluate the potential spatial distribution of the species. *Rojasianthe superba* has a higher probability of occurrence in the country highlands and also a high probability of extending its range in the volcanic chain, where it has been found in some isolated sites. Elevation was the most important variable explaining this potential distribution. These high altitude montane forests where *R. superba* occurs have been identified as endemism sites for different taxa in Guatemala.

Key words

Chimaltenango; Guatemala; montane forests, Neotropics; new record; Volcanic Chain.

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Introduction

The greatest biodiversity on the planet is in the tropical realm. Unfortunately, knowledge of the composition of assemblages and number of species is very poor for most groups of tropical organisms. Consequently, their conservation status is unknown, which limits the possibilities of implementing sustainable biodiversity use strategies (Alonso-EguíaLis et al. 2014).

Central America has a complex geological history and a varied topography that has given rise to a high variety of ecosystems (Gentry 1982, Mittermeier et al. 2004). The Mesoamerican Hot Spot, which includes almost all of Central America, is the second most diverse in the world and hosts more than 17,000 plant species, including 3,000 endemic species (Mittermeier et al. 2004). At the same time, this region is vulnerable to extreme events due to global climate change because of weather and climatic stresses, as well as non-climatic stresses such as effects of demographic pressure and over-exploitation of natural resources. As threats continue to increase, biodiversity will become even more vulnerable (Magrin et al. 2007). Within the region, Guatemala is recognized as a megadiverse country (CONAP 2013) with a highly diverse flora that is estimated at 10,317 species (Véliz

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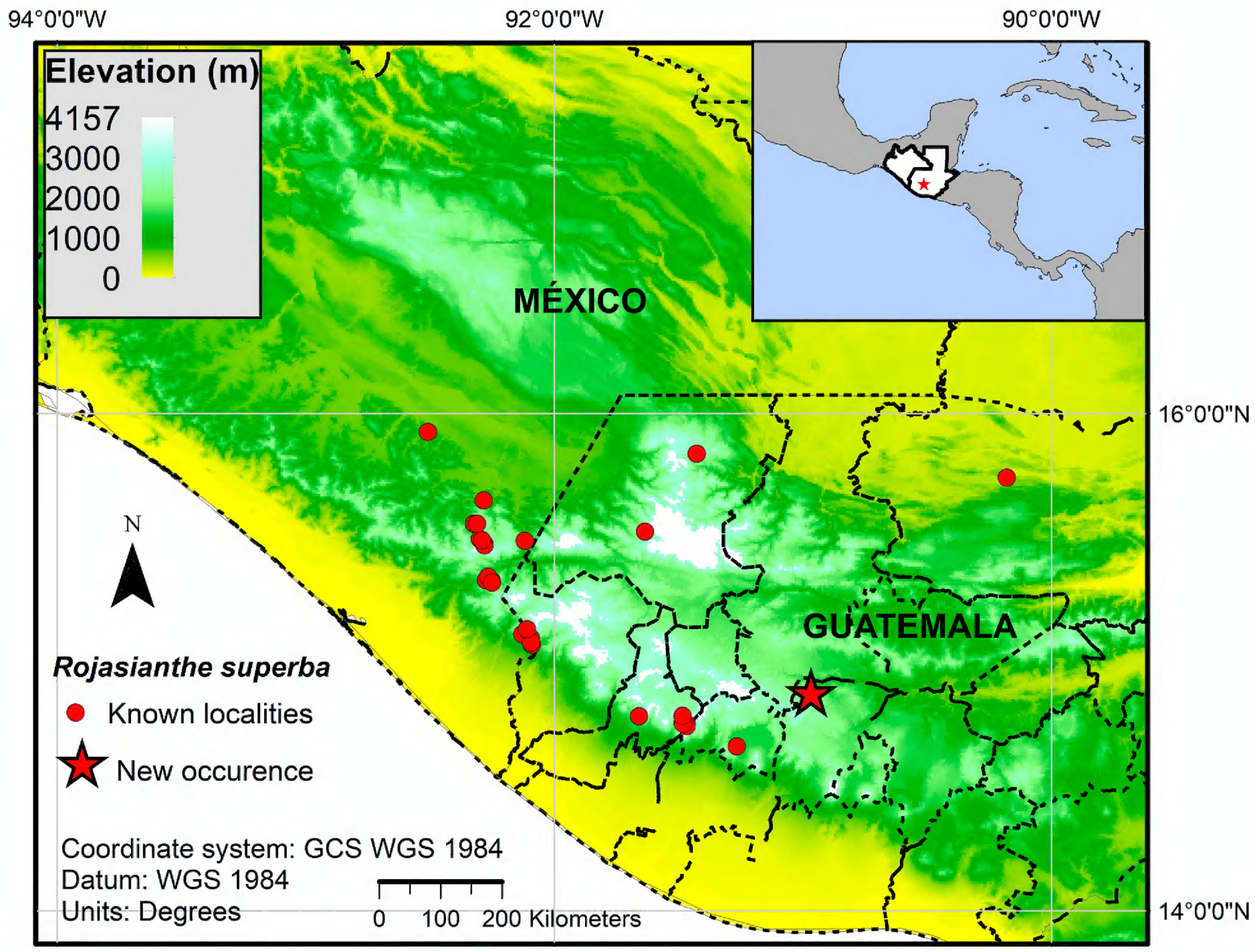

Figure 1. Known localities of geographic distribution of *Rojasianthe superba*, and new record in Chimaltenango, Guatemala. The colors palette indicates elevation in meters. The map box indicates the regional location of the species distribution in Chiapas (México) and Guatemala.

2008). However, significant habitat loss due to human land use is prevalent in several areas including some elevational bands of cloud forest in Western Guatemala (Quedensley and Bragg 2007).

Several plant genera are endemic to or largely restricted to the Guatemala/Chiapas region. Some of the most notable examples include *Rojasianthe* Standl. & Steyerm (Almeda 1993). It has been suggested that some of these genera may constitute relictual components of tropical flora that were widely distributed in the Eocene of North America and were largely decimated by Neogene climate changes (Breedlove 1981, Almeda 1993). Alternatively, tropical plants could have moved from South America to North America as the two land masses approached during the Tertiary (Raven and Axelrod 1974). *Rojasianthe* is a monospecific genus in the plant family Asteraceae: Heliantheae (Nash and Williams 1976, Plovanich and Panero 2004), that consists only of the shrubby species *R. superba* Standl. & Steyerm. It is usually found in narrow, wet, wooded ravines, in forests or on exposed slopes at 1300–3400 m elevation in Huehuetenango, Quezaltenango, San Marcos (type collection from Volcán de Tajumulco, between Las Canojas and top of ridge, *Steyermark 35835*) in Guatemala and also in Chiapas in Mexico (Nash and Williams 1976). One of the results of a floristic inventory carried out in April 2014 at the private natural reserve El Encanto de Tecpán in Guatemala was the finding of *R. superba* in a locality not previously included within the distribution range of the species. Here we report this new locality and the potential distribution of the species in the region resulting from computer models. The estimated potential distributions may provide additional information when planning strategies to mitigate the effects of climate change that might threaten the survival of high elevation species such as *R. superba* whose habitat has already been affected by anthropic activities (Quedensley and Bragg 2007).

Methods

During field efforts to survey the flora of Western Guatemala, a floristic inventory was carried out in the "El Encanto de Tecpán" private nature reserve in Chimaltenango department (Fig. 1). Several specimens were collected on 8 April 2014 including *R. superba*. Specimens were preserved using traditional methods in

plant systematics. Mounted specimens are housed at the botanical collection of the BIGU Herbarium, University of San Carlos de Guatemala (registration number 68629).

Species distribution models (SDM), based on the ecological niche modeling (ENM) theory (Soberón and Peterson 2005, Soberón 2007) were built to evaluate the spatial distribution of the habitat potentially available for *R. superba*. To run the models, information of 43 georeferenced collections of the species were used. These occurrence records were downloaded from the databases of the Global Biodiversity Information Facility (2017) and from the Missouri Botanical Garden (2017) database. Occurrence data were also gathered from specimens housed at the BIGU Herbarium. In addition, information on abiotic variables across the distribution area of the species was used. The variables used were 20 layers of bioclimatic digital information (temperature, precipitation, elevation), which were downloaded in raster format from Worldclim project database (Hijmans et al. 2005). Layers used were those with 30 seconds resolution and containing information on the current climatic conditions.

The range size of *R. superba* was estimated based on the distribution reported in the literature (Nash and Williams 1976, Quedensley and Bragg 2007, Pardo et al. 2009, Véliz et al. 2014) and from the occurrence records cited above. To adjust the models, the bioclimatic layers were cut to the size of the dispersion area that is hypothetically accessible for the species, using R software (R Core Team 2016). The criterion used to define this area was the presence of biogeographic barriers suggested by Barve et al (2011). The Isthmus of Tehuantepec in Mexico and the Nicaragua depression were established as hypothetical limits for the dispersal of the species to the north and to the south respectively. These barriers have been suggested as distribution limits for some organisms including plants (Gentry 1993, Hooghiemstra 2006, Kappelle 2006, Pérez-García et al. 2010 Aguirre-Planter et al. 2012, Bagley and Johnson 2014).

Using the occurrence data of the distribution of *R. superba* and selected abiotic variables, distribution models were estimated using the SDM package (Naimi and Araújo 2016) in software R (R Core Team 2016). We included 10 of the most commonly used modeling methods to produce potential species distributions (Li and Wang 2013, Elith et al. 2006). The newly developed SDM package in R allows for simultaneous comparisons among these various modeling methods regarding their performance (Naimi and Araújo 2016). The 10 models used were: 1) GAM (Generalized Additive Model), 2) RPART (Recursive Partitioning), 3) GLM (Generalized Lineal Models), 4) MARS (Multivariate Adaptive Regression Spline), 5) BRT (Boosted Regression Trees), 6) CART (Classification And Regression Trees), 7) SVM (Support Vector Machine), 8) Maxent (Maximum entropy), 9) RF (Random Forest) and 10) MaxLike. These algorithms or modeling methods were used, taking into account that there is not a single best algorithm for all cases. Their performance varies depending on the nature of the data. Therefore it has been suggested that species distribution modeling should start by testing a series of algorithms to evaluate their performance and then select the one that best explains the data (Li and Wang 2013, Qiao et al. 2014). For the training phase of the model, a total of 10,000 randomly distributed background points were used (gRandom method). Ten replicates were performed (n = 10) for the adjustment of the models using the method of partitioning the subsampling data, 30% of the data were used for the model evaluation.

The performance models obtained were evaluated according to the following criteria: TSS (True Skill Statistics: Allouche et al. 2006), AUC (Fielding and Bell 1997) and deviation (or Deviance). A map with probability values of *R. superba* distribution was obtained based on the GLM model (Fig. 4), which was the one that performed the best (TSS = 0.84, AUC = 0.94, deviance = 0.03). Of the 20 variables considered in the analyses, the most important abiotic variables for the distribution of *R. superba* were the following: a) average temperature of the wettest quarter (min = 6.9 ° C, max = 24.5 ° C, mean = 15.71 ± SD = 4.47), b) precipitation of the warmer quarter (min = 215mm, max = 1296 mm, mean = 634.49 ± SD = 229.25), and c) elevation (min = 754m, max = 3744m, mean = 2276.09 ± SD = 749.99).

Results

Specimens examined. Guatemala: Sololá, San Pedro la Laguna, Volcán San Pedro, (14°39′39″ N, 091°15′58″ W, 2860 m elev.), P. Pardo, 28 January 2005, PP 736, BIGU-31169; Quetzaltenango, Zunil, (14°45.66′ N, 091°28.18′ W, 2400 m elev.), T. Quedensley, 3 January 2006, T. Quedensley 2765, BIGU-38848; Quetzaltenango, Zunil, (14°45′16″ N, 091°28′58″ W, 2442 m elev.), T. Quedensley, 9 January 2007, T. Quedensle 5111, BIGU-41174; Quetzaltenango, Zunil, (14°44′32″ N, 091°28′03″ W, 2900 m elev.), T. Quedensley, 7 May 2005, T. Quedensley 1943, BIGU-41195; Quetzaltenango, Volcán Chicabal, (14°46′53″ N, 091°39′31″ W, 2400 m elev.), E. Triboullier, 15 March 2007, BIGU-39821; Quetzaltenango, Zunil, Fuentes Georginas, (14°45′08″ N, 091°28′54″ W, 2340 m elev.), M. Véliz & L. Velásquez, 12 June 2012, MV 23621, BIGU-60767.

New record. Guatemala: Chimaltenango, Tecpán, Chajaliyá, Panimachavac, El Encanto de Tecpán, (14°52′44″ N, 090°57′59″ W, 2325 m elev.), Bárbara Escobar-Anleu, 8 April 2014, BIEA 118, BIGU-68629.

The data underpinning the analysis reported in this paper are deposited at GBIF, the Global Biodiversity Information Facility (http://ipt.pensoft.net/resource?r=rojasianthe_ocurrence_guatemala&v=1.1).

Identification. Specimen identification was initially made by comparison with similar specimens in the BIGU herbarium and by literature review (Nash and Williams 1976, Véliz et al. 2014). The identification was verified

Figure 2. Specimen of *Rojasianthe superba* BIGU-60767. Photograph by Mario Véliz.

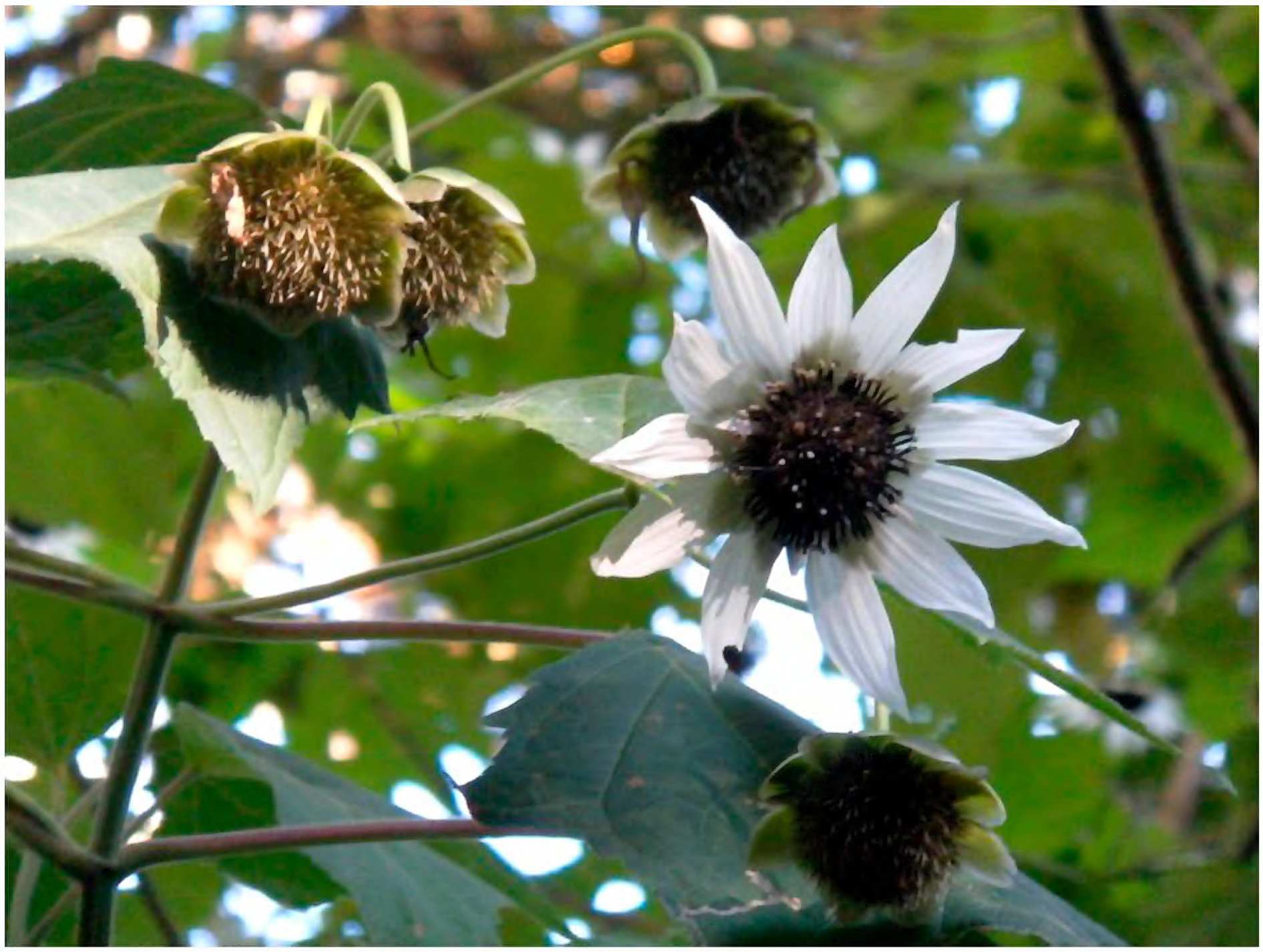

Figure 3. *Rojasianthe superba* from San Pedro Volcano, Sololá, Guatemala. Photograph by B. Escobar-Anleu.

by Mario Véliz, an expert in the flora of the region and curator of the BIGU herbarium.

***Rojasianthe superba* Standl. & Steyerm**
Figures 2, 3

Rojasianthe superba is a shrub, commonly 3–6 m tall and a suffrutescent trunk, sometimes as much as 10 cm in diameter. Petioles are 2–10 cm long and leaf blades are 10–22 cm long and 8–22 cm wide, ovate to triangular-ovate in outline, apically acuminate to long-acuminate, basally with an auricular appendage at the junction with the petiole, surfaces minutely scabridulous adaxially and abaxially. Inflorescences are 3–6 heads at each branch with phyllaries 3–seriate, obtuse, 1.5–2 cm long, disc 2.5–3.5 cm broad. Ray flowers are 12–15, with acuminate, white or purplish white elliptic ligules and ray pappus 1.5–2 mm long. Disc flowers are whitish, puberulent and achenes are about 6 mm long, with pappus 2–3 mm long (Nash and Williams 1976, Véliz et al. 2014).

R. superba was distantly related to *Montanoa* in spite of shared features such as accrescent pales, an $x = 19$ chromosome number, white ligules, and opposite leaves, but molecular studies indicate that the genus *Rojasianthe* is sister to *Montanoa* (Montanoinae) and to members of the subtribe Ecliptinae (Plovanich and Panero 2004).

Discussion

Guatemala's geological origins, climatic conditions, geographical location and topography have favored a high floristic diversity including unique species and areas with high concentrations of endemism (Véliz et al. 2014). Based on the distribution of endemic species richness, 12 key areas of floristic endemism have been identified in Guatemala. Some of these areas include Huehuetenango, the western volcanic chain, and Sierra de las Minas (Véliz et al. 2014). Mexico also constitutes a special case of high levels of endemism (more than 50% of its species are endemic) (Rzedowski 1993), with angiosperms as one of the most diverse groups in the country (Villaseñor 2003, Espejo-Serna et al. 2004) and Asteraceae as one of the families with the largest number of endemic genera (Turner 1996). Considering absolute, endemic and restrictive species richness, Chiapas is one of the areas with highest values for all the 3 types of richness as well as for climatic heterogeneity (Luna-Vega et al. 2013).

Endemic species represent a unique and important contribution to global biodiversity and are likely to become extinct as they combine vulnerability factors such as reduced geographic distribution, specific habitat requirements and reduced population size (Myers et al. 2000). Geographic patterns of endemic species have been suggested as guidelines for prioritizing conservation

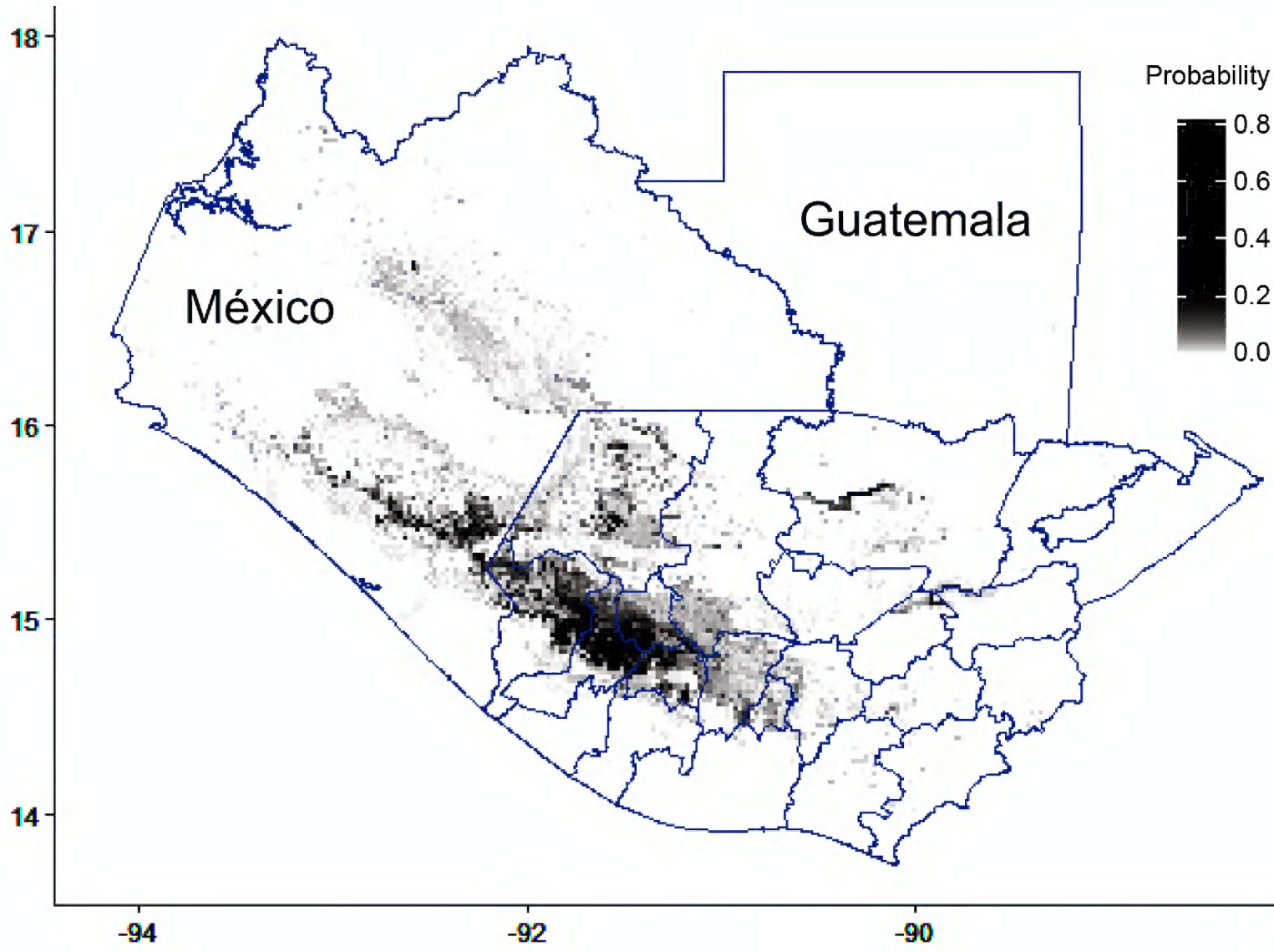

Figure 4. Potential habitat distribution of *Rojasianthe superba*, based on modeling with a GLM (Generalized Lineal Model) algorithm. GLM was the best evaluated model: TSS = 0.84, AUC = 0.94, deviance = 0.03). White areas indicates no probability of occurrence and darkest areas indicates highest probability of occurrence.

areas (Gaston 2000, Bonn et al. 2002, Orme et al. 2005, Lamoreux et al. 2006).

This NGD constitutes 2 main contributions regarding known information of the regional endemic *R. superba*: a new record at the departmental level (Chimaltenango) (Fig. 1) and an extension of the species distribution range: 40 km northeast in a straight line from the nearest point of known distribution. While realized or known distribution refers to the places where a species lives, potential distribution refers to the places where a species could live. The potential distribution of a species is a hypothetical concept that can be approached in a scenario where the distribution of the species is in equilibrium with the environmental space defined by certain variables (Jiménez-Valverde et al. 2008). In addition, the best evaluated model for the probable distribution of this species allows us to identify the potential distribution, where elevation is the most important variable determining this species' distribution (Fig. 4). The elevation range presented in this study (754–3744 m) represents an extension of the elevation limits of the species reported previously in the literature (1300–3400 m: Nash and Williams 1976).

Flora of Western Guatemala and Central and Southern México share a high number of species due to their similar ecological conditions and biogeographic history (Schuster and Bonis 2008, Luna-Vega 2008). Although there are many botanical collections from western Guatemala mountains, publications based on these specimens are still scarce, so there is little systematized knowledge of these floristic inventories (Bermúdez and Sánchez 2000). Although it is widely acknowledged that biodiversity knowledge is fundamental to base, justify and execute actions for its conservation (Knapp et al. 2001, Ejtehadi et al. 2005), especially in fragmented areas (Ponce-Vargas et al. 2006; Stevenson and Rodríguez 2008), there is a lack of information regarding congruence in endemism patterns at accurate scales, which is particularly unfortunate (Essl et al. 2011) and may have serious implications for management and conservation.

Our study identified the potential distribution of *R. superba* along the volcanic chain and the country highlands, particularly the western region where this species actually occurs. This means that *R. superba* is not likely to occur outside this restricted distribution.

Although this species has not yet been evaluated for its conservation status according to IUCN, characteristics such as its small range and endemism suggest that the species is probably Vulnerable. These sites where *R. superba* occurs, coincide with montane forests in the highlands of Guatemala, which have been identified as endemism areas for other taxa such as: bearded beetles (Schuster et al. 2000), herps (Acevedo 2006), birds (Eisermann and Avendaño 2009) and rodents (McCarthy and Pérez 2006) among others.

The potential distribution model that was generated, is an approximation to the estimation of the fundamental niche of the species (Hutchinson 1978, Peterson 2005, Soberón 2007) using some bioclimatic variables (Hijmans et al. 2005). Although there may be other abiotic variables that influence the species' distribution, as well

as biotic variables that can determine its presence on a smaller scale (Soberón 2007), the estimation of this potential distribution is important to generate initial hypothesis about the distribution and represent the information available for rare or little known species (Peterson 2001) such as *R. superba.*

Both the extension of the distribution range for *R. superba* and the potential habitat distribution model for the species, support the importance of Guatemala mountainous areas as priority sites for biodiversity conservation, especially endemic species as suggested previously.

The Guatemalan Protected Areas System (SIGAP) includes the volcanic peaks as protected sites (CONAP 2014). SIGAP is also working to include other areas (for example, undisturbed forest patches inside private farms). However, it is necessary to increase representativeness and connectivity of these areas in the SIGAP. Also, site management and planning should include alternative forms of resource use (for example communal lands), compatible with endemic species conservation in Western Guatemala.

The new record of *R. superba* for the Chimaltenango department emphasises the need to increase efforts to characterize Guatemala's biodiversity and its geographic distribution. Species distribution models based on ecological niche models are a very useful tool to reach this goal. However, they must be supported by georeferenced collection data. This will be best achieved by supporting and promoting field biological research.

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Author contributions

BE found the new record and collected the data; BE, JQ, and JM helped prepare the manuscript, and JQ analyzed the data and prepared the maps.

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